Hardy Australians: Ecogeography of *Cullen* suggests perennial legumes for low rainfall pastures

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Abstract

Perennial pastures are currently the most practical option for integrating perennials into existing Australian farming systems. Unfortunately, areas with acid soils, low rainfall, waterlogging or strong Mediterranean climates currently lack perennial pasture options. Native perennial plants may prove better suited than introduced perennial pastures to such areas. We evaluated native legume species from the genus *Cullen* based on the climate and soil characteristics of herbarium collection locations and their life history and growth form. Species with the best potential for further evaluation as pastures for Western Australia's (WA) wheatbelt were identified. Ten species of *Cullen* were found to be perennial, herbaceous and occur in areas with a low to medium, non-summer dominant rainfall pattern. Seven of these appeared adapted to the major soil types and soil limitations to plant growth found in WA's wheatbelt.

Introduction

Growing perennial pastures on a wide scale to reduce groundwater recharge is an attractive solution to manage the spread of dryland salinity as this approach allows farmers to continue to make productive use of their land and does not require major farming systems changes. Unfortunately, few commercially available perennial pasture legumes are well suited to the Mediterranean rainfall pattern in the wheatbelt of Western Australia (WA). The most widely adapted commercial perennial legume is *Medicago sativa* L. (lucerne) but this does not persist well in areas with acid soils, periodic waterlogging or low summer rainfall. Native perennial legumes are being screened to find perennial pastures suited to a broad range of growing conditions. It is expected that some Australian legumes may be especially tolerant to harsh conditions, since they have evolved with these conditions in their natural habitat.

Twenty-five species in the legume genus Cullen are endemic to Australia (Grimes 1997). Many *Cullen* species germinate easily, grow rapidly and produce seed prolifically and some have shown excellent drought tolerance and productivity in eastern Australian field trials (Dear *et al.* unpublished data). Further evaluation of agronomic characteristics, acidity tolerance and waterlogging tolerance of *Cullen* species is planned in glasshouse and field trials in WA, however, species of *Cullen* are variable with a range of life histories and growth forms, occurring on many soil types and under a range of climatic conditions. Some species are also known to produce antinutritional compounds, so not all *Cullen* species will be useful as pastures in the wheatbelt of WA. A selection of best-bet species is required to allow efficient evaluation of the genus for use as perennial pastures in WA's wheatbelt. This paper will attempt to select a subset of Australian *Cullen* species that are best suited to the WA wheatbelt based on life history, growth form, and climate and soil attributes of their natural distributions.

Methods

A recent generic review by Grimes (1997) was used to classify life history and growth form of *Cullen* species. ArcMap 8.3 (ESRI 2002) was used to plot the locations of herbarium collections of *Cullen* sourced from Australia's Virtual Herbarium (CHAH 2006). Collection sites were characterised by appending average annual precipitation (AAP) and average January precipitation data from the Australian National Land and Water Resources Audit (NLWRA 2005) and soil information from the Digital Atlas of Australian soils (DAAS 1991) and the 'Soil properties that affect land management' lookup table (BRS 1992). Rainfall seasonality of sites was estimated by calculating the percentage of AAP falling in January. Median AAP was used to summarise species rainfall requirements to reduce the effect of skewed data. The DAAS offered a practical classification of dominant soil types at the Northcote (1979) sub-division level. Further division of soil types by limitations to plant growth were based on the Northcote (1979) principle profile form (PPF) and the BRS (1992) lookup table. Species soil preferences were estimated using the percent of species collections found on each soil type and limitation combination.

The target zone in the wheatbelt of WA was defined using AAP, DAAS and the Geoscience Australia 'Australian Land Tenure 1993' (GA 2004) datasets. The suitability of each species to the target zone was estimated by comparing median AAP, rainfall seasonality of collection sites and species soil preferences. An overall soil suitability index for the WA wheatbelt (SSI) was also used for each species, calculated by summing over the seven major soil type/limitation combinations in WA's wheatbelt, the product of the species soil preference for a combination and the proportion of this soil combination in the target area of WA's wheatbelt (Equation 1).

Equation 1. Calculation used to assess the overall soil suitability index (SSI) for WA's wheatbelt for each species.

SSI = Σ (species preference for a soil combination ? proportion of soil combination in target area)

Life history and growth form

The primary selection criterion was life history. Perennial plants are likely to have deep roots that enable them to access water from greater depths, and perennials may be able use out of season rainfall. The second criterion was growth form. Herbaceous or semi-herbaceous plant morphology is most desirable because most above-ground plant parts can contribute to the productivity of the pasture. In addition, herbaceous or semi-herbaceous plants are more easily removed for subsequent crop rotations and can be temporally integrated with crops in specialised pasture-cropping systems.

Sixteen of the 25 Australian species of *Cullen* fit the herbaceous, perennial plant criteria (Table 1) (Grimes 1997). Twenty-two are described as perennial (p) or short lived perennial (slp), with *C. graveolens* and *C. plumosum* described as annual (a) and *C. walkingtonii* described as annual to biennial (a-b). Nineteen Australian *Cullen* species are described as herbs, herbs to subshrubs or herbs to shrubs, so fitting the ideotype growth form. Six Australian *Cullen* species are described as either shrubs or shrubs to trees.

Target Zone

Climate

Rainfall in the south-west of WA occurs mainly over winter and although significant falls of rain can occur during the summer months, these are unreliable. The total amount of rain that falls varies from over 1200 mm per annum (pa) in the extreme south west to around 300 mm pa on the northern and eastern fringes of the wheatbelt. Areas of the wheatbelt receiving between 650 and 300 mm pa rainfall are particularly deficient in perennial pasture options. Freehold land receiving between 650 and 300 mm average annual rainfall in the south west of WA covers an area of over 176 000 km^2 and will be considered here to represent the target area.

Plants adapted to growth in areas with tropical rainfall patterns are unlikely to persist well in the target area due to low rainfall over summer, an inability to compete with winter weeds and frost sensitivity. Plants from semi-tropical areas have a more flexible growing phase and are generally able to utilise rain that falls during summer or winter. Temperate zone plants are also well suited to the target zone, since there is water available during their active growth phase and they are able to avoid summer drought conditions through dormancy. Species with collection sites averaging more than 25% of AAP occurring in January will be considered adapted to a tropical climate and excluded from the best-bet selection.

In total, 20 Australian *Cullen* species appear adapted to areas with less than 650 mm pa rainfall and 17 species come from areas without a tropical climate. Eleven of the 16 perennial, herbaceous *Cullen* species had a median AAP of collection sites less than 650 mm. Of these 11 species, only *C. pustulatum* appeared adapted to a tropical rainfall distribution and so was excluded. *Cullen tenax* had the highest median AAP (640 mm pa) of the ten remaining species.

Soils

The target area of WA's wheatbelt has a relatively simple geology with only four major soil types as defined by Northcote (1979) accounting for 93% of the target area (Table 1). These are (in order of decreasing prevalence) duplex soils with a yellow/grey clay B horizon (Dy), non-calcareous gradational (Gn), uniform coarse (Uc) and duplex soils with a red clay B horizon (Dr). Limitations for plant growth can occur on these soil types where they are either shallow soils (SHAL), hard-setting clays (HSET), subject to periodic waterlogging (WLOG), acidic (ACID) or low in nutrients (LNUT). Sometimes, more than one of these limitations can occur in the same area. Most commonly, Dy soil types in the target area are WLOG or LNUT or less often ACID. ACID and LNUT limitations co-occur on 7.8% of Dy soil types in the target area. Gn type soils in the target area are often ACID and always LNUT. The most common limitation to plant growth on Uc soils in the target area is SHAL and on Dr soils is HSET. These seven soil type and plant growth limitation combinations account for 86% of the target area.

Table 1. Life history, growth form, climate adaptation, soil preferences and WA wheatbelt soil suitability index (SSI) for Australian species of *Cullen*. Bold text indicates perennial, herbaceous species adapted to the target climate. Figures in parenthesis below the soil type and limitation abbreviations show the percentage of the target wheatbelt area covered by soil types and soil type/limitation combinations. *n* denotes the number of herbarium collections used for analysis.

Species name	*n*	Life history	Growth form	Median AAP (mm)	AAP falling in January (%)	Soil preferences (% of collections on soil combination)							SSI
						Dy (52%)			Gn (17%)		Uc (13%)	Dr (11%)	
						WLOG (35.6%)	LNUT (16.1%)	ACID (8.1%)	LNUT (17%)	ACID (13.7%)	SHAL (10.8%)	HSET (6.2%)	
australasicum	**931**	**p**	**herb to shrub**	**260**	**15**	**1.6**	**2.1**	**2.3**	**8.5**	**0.3**	**17**	**1.6**	**4.5**
badocanum	297	p	herbs to subshrubs	1240	25	2.7	2.4	3.7	15.2	6.4	45.1	0.7	10.0
balsamicum	120	p	shrubs to trees	500	25	0.8	0	0	19.2	1.7	36.7	2.5	7.9
candidum	4	p	shrubs	640	29	0	0	0	0	0	25	0	2.7

cinereum	**530**	**p**	**herbs**	**360**	**19**	**0**	**0.2**	**0**	**11.7**	**2.5**	**14**	**4.2**	**4.1**
corallum	41	p	shrubs	600	30	0	0	0	4.9	0	63.4	0	7.7
cuneatum	15	p	herbs	700	26	6.7	0	0	6.7	0	53.3	0	9.3
discolor	**97**	**p**	**herbs**	**240**	**14**	**0**	**0**	**0**	**19.6**	**2.1**	**11.3**	**2.1**	**5.0**
graveolens	163	a	herbs	200	17	0	0	0	6.7	0	4.9	3.1	1.9
lachnostachys	45	p	shrubs	320	15	0	0	0	8.9	2.2	8.9	22.2	4.2
leucanthum	**243**	**p**	**herbs to shrubs**	**400**	**21**	**2.1**	**0**	**1.2**	**8.6**	**2.1**	**23.9**	**10.7**	**5.8**
leucochaites	70	p	shrubs	360	16	0	0	0	5.7	1.4	2.9	21.4	2.9
martinii	112	p	shrubs	390	24	0	0	0	9.8	0.9	42	13.4	7.2
microcephalum	172	p	herbs	820	9	12.2	0	4.7	19.2	15.7	1.7	1.2	10.4
pallidum	**297**	**slp**	**herbs to subshrubs**	**200**	**17**	**0**	**0**	**0**	**11.4**	**0**	**12.1**	**0.7**	**3.3**
parvum	**76**	**p**	**herbs**	**440**	**8**	**6.6**	**1.3**	**1.3**	**1.3**	**0**	**0**	**26.3**	**4.6**
patens	**198**	**p**	**herbs**	**280**	**16**	**3**	**0.5**	**0.5**	**22.2**	**2**	**13.1**	**3**	**6.9**
plumosum	50	a	herbs to subshrubs	590	26	0	2	0	24	14	34	0	10.0
pogonocarpum	**30**	**p**	**herbs**	**360**	**15**	**0**	**0**	**0**	**10**	**0**	**0**	**26.7**	**3.4**

praeruptorum	2	p	herbs	1090	24	0	0	0	0	0	50	0	5.4
pustulatum	179	p	herbs to shrubs	560	26	1.1	0	1.1	21.2	4.5	29.1	0.6	7.9
stipulaceum	**33**	**p**	**herbs to shrubs**	**360**	**18**	**0**	**0**	**0**	**0**	**0**	**6.1**	**27.3**	**2.4**
tenax	**337**	**p**	**herbs**	**640**	**13**	**18.4**	**0**	**8.3**	**8.6**	**3**	**0.6**	**4.5**	**9.5**
virens	24	p	herbs to shrubs	1280	27	0	0	0	0	0	62.5	0	6.7
walkingtonii	29	a-b	herbs	300	27	0	0	0	31	0	62.1	0	12.0

Of the 10 perennial, herbaceous species adapted to the target climate, two species (*C. australasicum* and *C. patens*) had records occurring on all seven soil type/limitation combinations (Table 1). *C. pallidum* occurred on three combinations and *C. pogonocarpum* and *C. stipulaceum* occurred on two. Five of the 10 species occurred on Dy WLOG and nine occurred on Gn LNUT, the most and second-most prevalent soil type/limitation combinations in the target area, respectively. *C. tenax* had the highest percentage of collections on Dy ACID and Dy WLOG over all 25 species (Table 1). *C. patens* had the highest proportion of collections on Gn LNUT over all species. None of the 10 species were found particularly often on Dy LNUT or Gn ACID, with the highest proportion of collections on these combinations being *C. australasicum* and *C. tenax*, respectively. Of the 10 species *C. leucanthum* and *C. stipulaceum* had the highest proportion of collections for Uc SHAL and Dr HSET, respectively. *C. tenax* had the highest proportion (11.3%) of collections on ACID limitations and *C. patens* had the highest proportion (22.7%) of collections on LNUT limitations.

C. tenax scored highest of the 10 species in the soil suitability index (Table 1), followed by *C. patens* and *C. leucanthum*. *C. pallidum*, *C. pogonocarpum* and *C. stipulaceum* all had SSI scores below 3.5.

Discussion

Based on life history, growth form and climate adaptation, 10 Australian *Cullen* species have been identified that appear to be suitable for further evaluation as perennial pastures in the wheatbelt of WA. However, further selection of best-bet species using adaptation to soil types is possible.

Cullen tenax in particular, stands out among the 10 as being the best suited to the soil type and limitation combinations present in WA's wheatbelt, reflected in its high SSI score. Particularly interesting was the apparent adaptation of *C. tenax* to the two most prevalent soil types in WA's wheatbelt, Dy WLOG and Gn LNUT, and its apparent adaptation to ACID soils. However, with a median AAP of 640 mm pa, the tolerance of *C. tenax* to low rainfall climates may be questionable. *C. stipulaceum*, *C. pallidum* and *C. pogonocarpum* appear least adapted to soils in WA's wheatbelt and are unlikely to be useful for widespread use in WA's wheatbelt.

Our results indicate that *C. australasicum*, *C. cinereum*, *C. discolor*, *C. leucanthum*, *C. parvum*, *C. patens* and *C. tenax* are perennial, herbaceous, adapted to the climate and moderately to well adapted to the soils of WA’s wheatbelt. These seven species warrant further evaluation as novel perennial pastures. The next logical stage of evaluation is to ‘ground truth’ these result in field trials and glasshouse studies to test tolerance to drought, soil acidity, waterlogging and productivity under low nutrient conditions. It seems likely that these studies and a thorough evaluation of agronomic characteristics on the seven best-bet species will identify a species of *Cullen* for further breeding, selection and development that is naturally well suited to use as a perennial pasture in WA’s wheatbelt.

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